Team

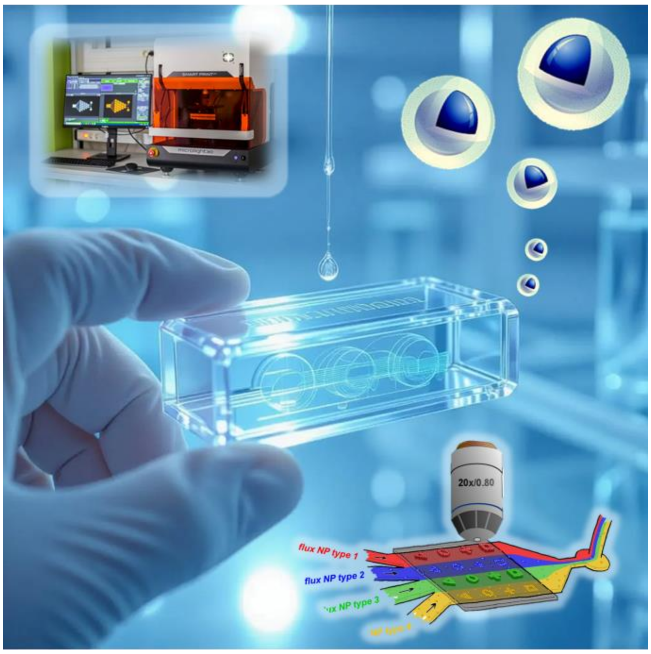
Master 2 Internship / PhD track

Probing Micropollutants in Water: Development of a Microfluidic Sensor Based on a Network of Enviro-Intelligent Nanoparticles

Equipe Nanotech au Laboratoire de Physique et Chimie des Nano-Objets (LPCNO-UMR 5215 INSA-CNRS-UPS) @ Toulouse

- Multidisciplinary experimental project in nanotechnology
- Final-year Master's (M2/Grande École) internship — minimum 5 months. The project will continue as a fully funded PhD from Sept–Oct 2026 to 2029.

KEYWORDS: sensor, microfluidics, water analysis, colloidal nanoparticle, directed assembly, micro/nanofabrication



Introduction – Monitoring micropollutants in water is a major societal challenge. Indeed, the contamination of rivers and streams by substances of anthropogenic origin — such as chemical discharges from industrial and agricultural activities or from nuclear power plant cooling systems — represents an increasing threat to both the environment and public health. This issue also highlights the importance of ensuring rigorous traceability of water intended for human consumption, in light of the potential presence of heavy metals, endocrine disruptors, and microplastics.[1]

The goal of this project is to develop a new generation of micro-sensors in the form of microfluidic chips capable of detecting, *in situ* and with extreme precision, the presence of several of these elements in minute quantities of water.

To achieve this, the sensitive area of the micro-sensor will be composed of a network of different types of nanoparticles, each with specific and selective binding properties toward given (micro)contaminants. Detection and quantification will rely on the photoluminescence response of the nanoparticles, whose emission wavelength and intensity will vary accordingly. The micro-sensor, fabricated from epoxy resin,[2] will exploit various microfluidic phenomena and functionalities such as laminar flow generation, the integration of "gradient"-type structures, and an electrostatic directed-assembly technique known as *nanoxerography*.

Project Overview - This innovative project is structured into several tasks, each representing a scientific and technical challenge for the candidate:

• Optical induction of electrostatic charges *in situ* in microfluidics.
Over the past fifteen years, the Nanotech team in Toulouse has developed an innovative technique known as *nanoxerography* — a process that consists in injecting electrostatic charges into an electret material in the form of patterned motifs of interest.[3] These charged patterns then serve as electrostatic traps for assembling charged and/or polarizable nano-objects initially dispersed in solution.Several parallel injection methods for patterning millimetric surfaces already exist, but all currently rely on the use of a physical mask or stamp.[4],[5] The objective here is to propose a new optical charge-induction method using a digital UV DMD[6] masking system, which could ultimately be implemented by optical transparency directly within the microfluidic sensor. To this end, and in collaboration with the Grenoble-based company Microlight3D, a brand-new setup will be installed, on which the selected candidate will be trained.

• Simultaneous co-assembly via microfluidic nanoxerography.
To minimize fabrication steps and enable multiplexed analyses on a single water sample, the aim will be to assemble at least three different types of nanoparticles simultaneously on predefined zones. This will require exploiting the laminar co-flow phenomenon[7] of colloidal dispersions, integrated into the nanoxerography process — a proof of concept of which has already been demonstrated in a previous PhD project. The functionalized polymer-coated gold nanoparticles used will be synthesized by collaborators from the Softmat laboratory in Toulouse.

• Micro-sensor characterization.
This stage will involve verifying the selectivity of microcontaminant absorption/adsorption by the various polymer coatings surrounding the nanoparticles, as well as the reversibility of detection. A regeneration protocol (e.g., by varying pH, temperature, or using a buffer solution flow) will need to be developed to desaturate the nanoparticle network and reset the detection system. Finally, sensitivity tests will be conducted using gradient-type microfluidic structures, allowing simultaneous testing of multiple micropollutant concentrations to determine the associated detection threshold.

Candidate Profile - Master's level (M2) or final-year engineering student.
Preferred background: Physics, Microfluidics, Micro/Nanotechnologies, Nanoscience.

The intern will join the Nanotech team, where they will receive training in microfluidic equipment use, micro/nanostructuring processes related to the *nanoxerography* method, and characterization techniques for nanoparticle assemblies.The candidate should demonstrate a strong interest in experimental work, most of which will take place in the team's cleanroom facilities. A dynamic, rigorous, and scientifically curious mindset will be essential to successfully carry out this research.

Priority will be given to candidates interested in pursuing the project as PhD students.

Contact Interested? Feel free to reach out to Laurence Ressier and Etienne Palleau to discuss the project in more detail and assess your fit for this position.

laurence.ressier@insa-toulouse.fr / epalleau@insa-toulouse.fr - tél : 05.61.55.96.72 / 05.61.55.96.37

Références

(1) Yang, Y.; Zhang, X.; Jiang, J.; Han, J.; Li, W.; Li, X.; Yee Leung, K. M.; Snyder, S. A.; Alvarez, P. J. J. Which Micropollutants in Water Environments Deserve More Attention Globally? *Environ. Sci. Technol.* **2022**, *56* (1), 13–29. https://doi.org/10.1021/acs.est.1c04250.

(2) Raffy, S.; Palleau, E.; Calvignac, B.; Brotons, G.; Lefebvre, G.; Rolley, N.; Teychene, S.; Viguier, B.; Cerezo, S. C.; Truan, G.; Ressier, L. "All in One" Epoxy-Based Microfluidic Chips at Your Fingertips. *ACS Appl. Polym. Mater.* **2021**, *3* (2), 801–810. https://doi.org/10.1021/acsapm.0c01112.

(3) Palleau, E.; Ressier, L. Combinatorial Particle Patterning by Nanoxerography. *ADVANCED FUNCTIONAL MATERIALS* **2018**, *28* (30). https://doi.org/10.1002/adfm.201801075.

(4) Poirot, D.; Platel, R.; Alnasser, T.; Guerin, F.; Palleau, E.; Ressier, L. Smartphone-Identifiable Photoluminescent Nanoparticle-Based Multilevel Secured Tags by Electrical Microcontact Printing. *ACS Appl. Nano Mater.* **2018**, *1* (10), 5936–5943. https://doi.org/10.1021/acsanm.8b01634.

(5) Diaz, R.; Palleau, E.; Poirot, D.; Sangeetha, N. M.; Ressier, L. High-Throughput Fabrication of Anti-Counterfeiting Colloid-Based Photoluminescent Microtags Using Electrical Nanoimprint Lithography. *Nanotechnology* **2014**, *25* (34), 345302. https://doi.org/10.1088/0957-4484/25/34/345302.

(6) Rao, Y.; Gao, Y.; Luo, N. Research and Design on DMD Digital Photolithography System. In *5th International Symposium on Advanced Optical Manufacturing and Testing Technologies: Design, Manufacturing, and Testing of Micro- and Nano-Optical Devices and Systems*; SPIE, 2010; Vol. 7657, pp 166–175. https://doi.org/10.1117/12.865240.

(7) Guerrero, J.; Chang, Y.-W.; Fragkopoulos, A. A.; Fernandez-Nieves, A. Capillary-Based Microfluidics—Coflow, Flow-Focusing, Electro-Coflow, Drops, Jets, and Instabilities. *Small* **2020**, *16* (9), 1904344. https://doi.org/10.1002/smll.201904344.